THE RIVER ANNAN DISTRICT

SALMON FISHERY BOARD

Assessment of Man-made Barriers to Fish Migration in the River Annan Catchment

March 2011

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Contents

Abbreviations

Annan DSFB: River Annan District Salmon Fisheries Board
NIEA: Northern Ireland Environment Agency
RAFTS: Rivers and Fisheries Trusts of Scotland
SEPA: Scottish Environment Protection Agency
SNH: Scottish Natural Heritage
SNIFFER: Scotland and Northern Ireland Forum for Environmental Research
WFD: Water Framework Directive

1 Introduction

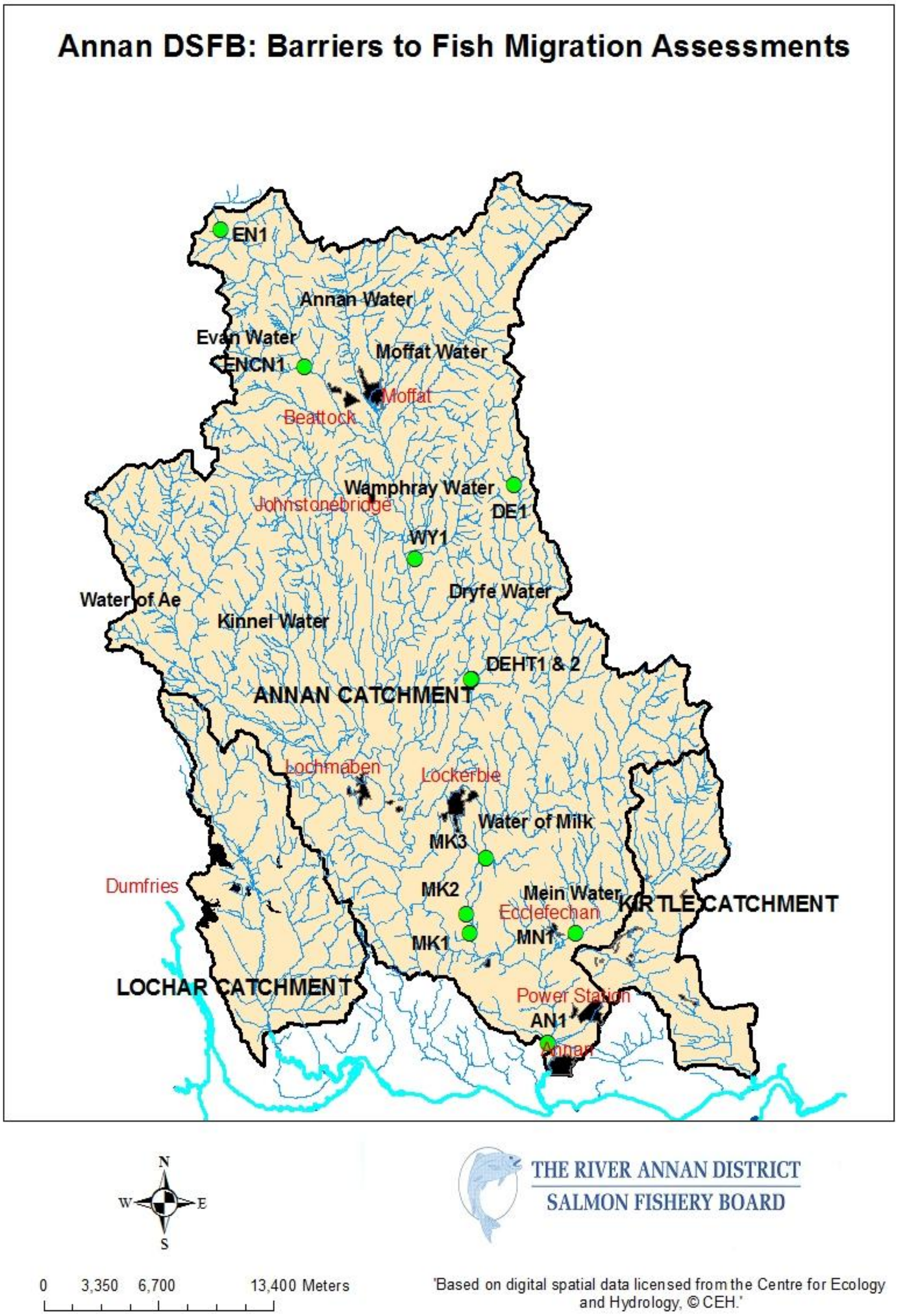
The WFD requires that Member States aim to achieve "Good Ecological Status" or "Good Ecological Potential" in the case of heavily modified water bodies, by 2015. It is recognised that one of the most effective mechanisms to achieve this is to mitigate for the impact of barriers on ecological processes such as those described by the River Continuum Concept (Vannote *et al.*, 1980). To assist in the assessment of rivers under the WFD and in prioritising resources for river restoration, environmental agencies and fisheries organisations need to be able to quantify the extent to which a barrier poses an obstacle to fish migration.

In 2008, SEPA commissioned a method for assessing the porosity of barriers with SNIFFER commissioning further work to validate the method in the field (SNIFFER website). With SNIFFER acting as the lead organisation, the NIEA and SEPA as funding collaborators, technical guidance from SEPA, NIEA, the Environment Agency, SNH, Fisheries Committee, Marine Scotland, RAFTS, Loughs Agency and Scottish Water and with the Centre for River Ecosystem Science as contractors, a methodology for assessing barriers to fish, together with a training package, has been completed (SNIFFER 2011). The first training course for this new technique, entitled "A Coarse Resolution Rapid-assessment Methodology to Assess Barriers to Fish Migration", was delivered at the SEPA offices in Hawick in 2010 with the author of this report amongst the trainees.

In early 2011 the Annan DSFB, part-funded by a portion of the Scottish Executive Fisheries Management Planning grant administered by RAFTS to member organisations, used this technique to assess eleven man-made obstructions to fish migration throughout the River Annan catchment (Figure 1.1). This report will briefly comment on the methodology used, summarise the results for each barrier assessment, prioritise barriers for removal or alteration, discuss these results and offer an opinion as to the effectiveness and usefulness of the assessments. A full breakdown of the results for each barrier is included in Appendix 1.

Figure 1.1

The eleven barriers to fish migration assessed on the Annan Catchment



2 Methods

The methodology can be divided into three components. First, the potential for fish to pass the barrier is assessed. Second, an inventory of all potential barriers is constructed. Third, the inventory is used as a tool to help develop strategies that prioritise barriers for potential removal or mitigation (Kemp et al, 2008).

The complete methodology of barrier assessment is too extensive to detail here but can be found in the field manual (SNIFFER, 2010). To summarise, each barrier was assessed taking into account such as the type of barrier (e.g. swim barrier or jump barrier), water velocities, water depths, barrier dimensions and channel dimensions. Each barrier was then assessed for different types of migratory fish using the data gathered for these characteristics and comparing it with tables of estimates of passability (both upstream and downstream) for these fish groups. Fish were divided into different guilds as shown in Table 2.1 below.

Table 2.1

The different fish guilds used for assessment

Adult salmon
Adult trout
Adult grayling
Cyprinid/juvenile salmonid
Adult lamprey
Juvenile eel
Salmonid smolt
Juvenile lamprey
Adult eel

It was recommended that surveys were conducted at summer low levels. It is assumed that the resulting passability scores for adult salmonids will be underestimated. However, it is considered that summer low levels will provide a more accurate reflection of passability for such as juvenile salmonids, eels and lampreys. Surveying at summer low level is also encouraged to gain standardisation of results, minimise health and safety risks and provide information on barriers that may vary temporally (SNIFFER, 2010). Some of the barriers in this survey were assessed at low water levels as recommended but due to time constraints of the project others were measured at elevated level. Measurements were only taken at elevated level at structures where there were no health and safety implications and there was visually little difference in the flow characteristics at different water levels. In a slight deviation from the recommended procedure it was decided that rather than have only two recorded values, one measured at lower water and one calculated at higher water, three values of passability were recorded at some barriers (two of these estimated). This was carried out as it was deemed the obstacles had a very different likelihood of passability at these levels.

Barrier passability may be defined as the proportion of fish that encounter an impediment and then successfully pass it (during either an upstream or downstream migration) without undue delay (i.e. the probability of reaching the final destination, e.g. spawning or feeding grounds, is not compromised due to such as increased energetic expense or predation risk) (e.g. Bull, 2010, Haro *et al.*, 2004). To this end the passability of barriers for each fish cohort was based on four scores devised for the assessment as follows:

Complete barrier (value = 0.0):
It is the opinion of the assessor that the target species / life-stage, or species guild cannot pass the barrier

Partial high impact barrier (value = 0.3):
It is the opinion of the assessor that the barrier represents a significant impediment to the target species / life-stage, or species guild, but some of the population (e.g. < one-third) will pass eventually; or the barrier is impassable for a significant proportion of the time (e.g. > two-thirds).

Partial low impact barrier (value = 0.6):
It is the opinion of the assessor that the barrier represents a significant impediment to the target species / life-stage, or species guild, but most of the population (e.g. > two-thirds) will pass eventually; or the barrier is impassable for a significant proportion of the time (e.g. < one-third).

Passable barrier (value 1.0):
It is the opinion of the assessor that the barrier does not represent a significant impediment to the target species / life-stage, or species guild, and the majority of the population will pass during the majority of the period of migration (movement). This does not mean that the barrier poses no costs in terms of delay, e.g. increased energetics, or that all fish will be able to pass.

The above barrier assessment results were then added to an inventory for each site along with any known densities of fish and estimates of length of available habitat upstream (calculated using Arcview GIS). A list of prioritisation for removal or alteration was then drawn up taking these factors into account.

3 Summary of Results

3.1 An1 (main-stem Annan: E319009N568229)

Figure 3.1

The majority of structure An1 was deemed impassable due to the height and gradient of the weir as shown in Figures 3.1 a) and b). Figure c) does not show rectangular notches which are present but obscured at both the forefront and rear of the fish pass. These notches allow for the upstream passage of adult Atlantic salmon (*Salmo salar*), brown/sea trout (*Salmo trutta*) and grayling (*Thymallus thymallus*) possibly as a low impact barrier. It is estimated that the fish pass represents a high impact barrier to cyprinids and juvenile salmonids and a complete barrier to adult lampreys due to water velocities. Juvenile eels (*Anguilla Anguilla*) may utilise climbing substrate at either end of the weir. It was considered that downstream migration was not an issue for any cohort of fish. It should be noted that this structure could not be measured for velocities or depths and the above estimates are purely subjective.

3.2 MN1 (Mein Water: E320612N574454)

Figure 3.2

Photographs of structure MN1 looking upstream at a) low water and b) elevated level. Figures c) and d) were taken at elevated level and show a side elevation and downstream view respectively

The vertical leap in the forefront of figure 3.2 a) and b) shows little difference in height between low water and elevated level. This jump was recorded as no barrier for adult salmon, a low impact barrier for adult trout and a complete barrier to all other guilds other than juvenile eels which may utilise the climbing substrate circled in Figure 3.2 a). The sloping weir beyond this was a complete barrier at low water to the upstream migration of adult salmon, adult trout, adult grayling and cyprinids mainly due to shallow water. It was estimated that variable combinations of water depths and velocity made this a low impact barrier for these guilds at elevated level. The effective length of the structure made it either a low or high impact barrier to the other cohorts at any water level. In summary, only adult salmon and trout and juvenile eels are likely to migrate upstream of both the leap and slope to some extent. For these guilds (adult eels rather than juvenile) migration downstream is likely to be best attempted at higher water levels. One or two rocks at the bottom of the vertical drop recorded this as a low impact barrier.

3.3 Mk 1 (Water of Milk: E314492N574495)

Figure 3.3

Photographs of barrier MK1 at a) low water b) elevated level c) bankfull level and d) bankfull level looking upstream

The data deemed the barrier to be completely impassable upstream at low water to all cohorts (other than juvenile eels) with shallow water being the main limiting factor. Juvenile eels may utilise suitable climbing substrate on the right bank (circled in Figure 3.1a). The most likely route upstream for adult salmon and trout (supported by anecdotal evidence) appears to be the right bank area at elevated levels (Figure 3.1b) although turbulence and water velocity should make this a barrier for weaker and smaller fish. It seems unlikely that adult grayling, adult lampreys, cyprinids or juvenile salmonids can pass at elevated level. The barrier appears to be impassable to all cohorts upstream at bankfull level due to water velocity and turbulence as shown in Figure 3.1c. Figure 3.1 d shows a small adult salmonid attempting to jump what is essentially a swim barrier at elevated level. It has been recorded that noise associated with the hydraulic jump created at the transition point may attract fish and initiate leaping behaviour (Kemp *et al*, 2008). Around 15 unsuccessful leaps were witnessed by the author at this time. It is highly unlikely that even larger fish would be able to negotiate the obstacle in this manner at any water level. The shallow nature of the structure at low water makes it likely that downstream migration of adult salmon, adult trout, adult grayling, cyprinids and juvenile salmonids is not possible. Juvenile lampreys and adult eels should be able to migrate downstream at all river levels. All cohorts should be able to pass downstream at elevated and bankfull levels.

3.4 Mk 2 (Water of Milk: E314278N575481)

Figure 3.4

Photographs of barrier MK2 at a) low water b) elevated level and c) bankfull level

There appears to be no barrier to the downstream migration of any cohort at all water levels. The central section circled in Figure 3.2a is around 1.5m in width with a small vertical brick wall running lengthwise either side (obscured in photo). This has created a deeper channel with slower water velocities allowing the upstream migration of fish at low water levels. Water turbulence acts as a low impact partial barrier for adult salmon and trout and a high impact partial barrier for adult grayling. It is unlikely that cyprinids, juvenile salmonids or adult lampreys can pass upstream. It is estimated that only stronger adult salmon and trout can pass upstream at elevated levels within the section circled in Figure 3.2b. The water velocities and turbulence shown in Figure 3.2c appear too great for any cohort to migrate upstream at bankfull level. The exception to this is juvenile eels which may utilise climbing substrate (circled) on the right bank.

3.5 Mk 3 (Water of Milk: E315425N578749)

Figure 3.5

Photos of barrier MK3 looking upstream at a) low water b) elevated level c) bankfull and d) an unsuccessful salmonid leap

The most likely source of upstream migration appears to be transversal section 2 at low water (circled in Figure 3.5 a). Slightly shallow water at the foot of this part of the structure meant it was recorded as a partial low impact barrier for adult salmon, trout and grayling. Water velocity at the foot was assessed as causing a high impact barrier to juvenile salmonids and cyprinids and a complete barrier to adult lampreys. It is likely that high velocities and turbulence make this section impassable to all at elevated and bankfull level. There was climbing substrate present for juvenile eels but the effective length made it a high impact barrier. Transversal section 1 was impassable to all due to a combination of shallow water, velocity and high gradient at the foot of the slope. Transversal section 3 was impassable to all upstream mainly due to sections of little or no water. Transversal section 4 appeared to be impassable to all cohorts due to the height of the vertical jump and very high turbulence below. The author witnessed around 25 attempts by adult salmon to leap this part of the obstruction at elevated level, none of them successful (Figure 3.5d). There were a few points on the structure where downstream migration could be negotiated safely by all guilds.

3.6 DEHT1 (Dryfe Water, Howthat Burn: E314560N588879)

Figure 3.6

Photographs of barrier DEHT1 looking downstream at a) summer low level b) elevated level and c) bankfull level. Figure d) shows summer low level looking downstream

The small vertical jump pictured had a moderate degree of turbulence at elevated level when the barrier was assessed (Figure 3.8b). This was deemed as creating a low impact barrier for adult salmon, trout and grayling. The height of the leap made the impact greater for adult cyprinids/juvenile salmonids (complete barrier) and adult lampreys (high impact barrier). Juvenile eels are likely to utilise climbing substrate on the right bank. The culvert itself was 38m in length and this length, shallow water depths and water velocities too great for some cohorts combined to make the structure impassable upstream to all guilds. The length of the structure will require greater burst energy expenditure for fish than shorter obstacles and also helps to create the shallow depths that were measured here (SNIFFER 2010). This lack of depth meant the barrier was deemed impassable downstream to adult salmon and trout and as creating a high impact barrier for adult grayling, cyprinids/juvenile salmonids, salmonid smolts and adult eels. It was estimated that only juvenile lampreys could pass downstream unimpeded. Although the photos above were all taken at slightly different angles it is apparent there was very little difference visually in terms of water depth and turbulence. There may be some difference in water velocities at low and bankfull levels but the results calculated at elevated level are unlikely to deviate a great deal at these other levels, particularly as the effective length of the structure was a major limiting factor.

3.7 DEHT2 (Dryfe Water, Howthat Burn: E314523N588908)

Figure 3.7

Photographs of structure DEHT2 looking downstream at a) summer low level and b) bankfull. A downstream view is shown in c) at the elevated level during the survey. Figure d) shows the first of a few natural obstructions immediately upstream

Figures 3.7 a), b) and c) show obstacle DEHT2 at 3 different water levels. The water depths on each step and turbulence levels both across each step and the plunge pool below combine to make the structure impassable both upstream and downstream to all cohorts of fish. The water velocities recorded at elevated level were also a limiting factor for the majority of guilds. Taking into consideration the impassable results of DEHT1 and 2 and the natural obstacles above DEHT2 (Figure 3.7d), it seems certain that no migratory fish will be found in the watercourse above. The Annan DSFB holds limited electrofishing data above these obstacles which yielded 3 juvenile trout and 1 stickleback. It is likely that the trout are resident fish.

3.8 DE1 (Dryfe Water: E317050N599907)

Figure 3.8

Photographs of obstacle De1 at a) Elevated level looking upstream b) elevated level looking downstream and c) Bankfull level looking upstream

The main limiting factor upstream appeared to be the build up of substrate inside the end of three of the five pipes (obscured in Figure 3.8b). This created a small vertical jump which most fish would not be likely to pass without a greater depth of water. This was exacerbated by the creation of smaller openings for the fish to pass through which would be problematic for larger fish. There was an element of chance as 2 of the pipes were relatively clear but the addition of other limiting factors such as turbulence meant the barrier was assessed overall as a high impact barrier to all cohorts upstream. The exception to this is juvenile eels which may utilise climbing substrate. The combination of the vertical leap shown in Figures 3.8a and c and the water velocities and depths within the pipes were measured as having no major impact on any cohort other than adult lampreys, although it is likely that some fish will miss the pipe entrances (possibly damaging themselves in the process) or even end up on the road crossing when leaping. All measurements were taken at elevated levels as shown in Figure 3.8a but there was little difference visually at close to bankfull level as shown in Figure 3.8c. The biggest impact on downstream migration was deemed to be rocks below the downstream end of 2 of the pipes and the barrier was recorded as a low impact barrier for all cohorts. Historical electrofishing data has shown low numbers of juvenile salmonids present above the structure after 2006. Before this there were substantial numbers of juveniles to be found. An extreme flood event in 2006 altered the previously passable structure and surrounding watercourse to their present state.

3.9 WY1 (Wamphray Water: E311250N595730)

Figure 3.9

The photographs below show barrier WY1 looking upstream at a) low water and b) bankfull levels. Figure 3.9 c) Shows the structure at low water looking downstream and d) shows a side elevation of the higher of the two jump barriers at low water

The smaller of the two jump barriers within the structure (foreground in Figure 3.9a) is likely to be passable to only adult salmon and trout due to height although the extreme turbulence at higher water levels is likely to act as a low impact partial barrier to these fish. The swim barrier above this is impassable to all guilds at all water levels due to a combination of high velocity, low water depth and effective length. An idea of the velocity on the slope can be seen by the wave created in Figures 3.9 c) and d). In the highly unlikely event that any fish negotiates this part of the obstacle then the jump barrier beyond this (Figure 3.9d) is also impassable due to height, gradient and the lack of any substantial pool to leap from. This assessment is consistent with electrofishing data which has found only juvenile trout (likely to be resident) above the structure other than years following stocking when some salmon fry may be present. The structure is likely to be passable to all cohorts in a downstream direction with a possibility of some damage to larger fish at the bottom of the higher vertical drop due to lack of a reasonable plunge pool.

3.10 ENCN1 (Evan Water, Cloffin Burn: E304856N606635)

Figure 3.10

Photographs of barrier ENCN1 at low water a) lower culvert upstream b) lower culvert downstream c) upper culvert upstream and d) upper culvert downstream.

Although barrier ENCN1 was a single transversal section it consisted of two continuous but very different culverts. It was decided to score these as individual transversal sections to assess the differences between them. Figures 3.10 a) and b) show the lower culvert which had good water depth and low velocities which would be unlikely to hinder any guild moving upstream. The energy expenditure for fish in culvert 1 is likely to be low and the effective length of culvert 1 was not added to that of culvert 2 when assessing this criteria overall. However, the effective length of culvert 2 alone was over 38m and recorded as creating an impassable barrier upstream to all but adult salmon and trout. For adult salmon and trout, water depth and effective length created a complete barrier and high impact barrier scores respectively. Water depth at bankfull level may allow smaller salmon to pass upstream and so the structure is classed as a high impact barrier at this level. Downstream migration was classed as high impact for adult salmon, trout and grayling, low impact for salmonid smolts and adult eels and no barrier for juvenile lampreys. The impacts are likely to be reduced at higher water levels. The historical electrofishing data for the Cloffin Burn shows juvenile salmon numbers to be very poor and trout densities to be fair using the Annan DSFB grading system. It is unknown what proportion of these trout where spawned from adult sea trout but the figures appear consistent with the barrier assessment.

3.11 EN1 (Evan Water: E299973N614373)

Figure 3.11

The photos below show the barrier steps of EN1 upstream at a) Low water and b) bankfull level. Figure c) shows the aquaduct swim barrier above the steps upstream at low water.

The water velocity and turbulence shown in Figure b) at bankfull level is greater than that at low water in figure a). However, there is no great difference in water depth and the lack of any pools to leap from combined with the height of the steps (smaller fish) make this barrier impassable upstream to all cohorts at all water levels. The sloping aquaduct, which crosses the railway line, could not be accessed for its full length due to fencing as displayed in Figure c). Assuming the velocity and depth measurements taken at the accessible section were similar at all sections then a partial barrier would be created for all cohorts both up and downstream apart from juvenile eels. However, due to the length of the slope (estimated at 70m) it is likely that this sloping section is a complete barrier to all upstream migration at any time. The absence of reasonable water depth would also make the aquaduct a high impact barrier for the downstream migration of adult salmon, adult trout, adult grayling and cyprinids and a low impact barrier for adult eels and juvenile salmonids. There would appear to be no downstream barrier for juvenile lampreys.

3.12 Estimates of available upstream habitat

Table 3.1

List of estimated lengths (km) of available habitat upstream of barriers

Barrier	Estimated Habitat Length Upstream (km)
AN1	1000 (km^2)+
MN1	11
MK1	50+
MK2	50+
MK3	45+
DEHT1	6
DEHT2	6
DE1	5
WY1	11
ENCN1	4
EN1	6

3.13 Prioritisation of Barriers

Table 3.2

Table of priority for barrier removal or alteration (No. 1 being highest priority)

Barrier	Priority Number
WY1	1
EN1	2
AN1	3
MN1	4
DE1	5
ENCN1	6
MK3	7
MK1	8
DEHT1	9
DEHT2	10
MK2	11

4 Discussion

4.1 Survey Results

The barrier WY1 was chosen as priority number one as it excludes all migratory fish from around 95% of one of the Annan's main tributaries. EN1 was number 2 as it excludes all migratory fish from around 6km of good habitat on another main tributary. An1 was third as although it allows access to most migratory fish to some extent it may exclude access to the majority of the Annan catchment for adult lampreys (see section 4.2). MN1, DE1 and ENCN1 were considered to be approximately equal in priority with migratory fish either in very low numbers or absent. MK1 and MK3 appear to act as partial barriers but it is known that there are decent numbers of fish upstream (see section 4.2). DEHT1 and DEHT2 excluded all migratory fish but investigation further upstream showed a number of natural obstructions which are likely to act as barriers. Structure Mk2 was considered to be of least concern.

4.2 Observed Value of Survey Methodology

There appears to be divided opinion on the merits of the survey methodology. Some people feel that fish population data from such as electrofishing surveys provides sufficient information on the passability of barriers. There is no doubt that that this data plays a large part in assessing potential obstructions but in many cases is unlikely to provide a complete picture. For example, the Annan DSFB possesses good historical electrofishing data on the Water of Milk which shows sites ranging from excellent through to very poor or absent for juvenile salmonids and certain parts of the watercourse could not be considered as being close to carrying capacity for juvenile life stages. Some of these poorer sites have suitable juvenile habitat and would support a greater number of fish so why is this not the case? There are obviously many variables to consider which could affect these populations such as eutrophication, sedimentation, toxic pollution or numbers of returning adults in any one year. However, as structures MK1 and MK3 in particular have been assessed as acting as a barrier to migration at least under certain flow conditions (and been witnessed by the author as being so) it seems reasonable to consider that these structures may be having an impact on salmonid populations. Partial or temporal barriers can block the movements of a proportion of the population that are weaker swimmers or younger life-stages. Even for those fish which eventually manage to pass, delayed migration can have significant impacts on such as individual energetic costs, predation risk, and timing of arrival at the final destination, potentially disrupting adapted physiological transition (e.g., smoltification and estuarine arrival for juvenile salmonids) (Kemp *et al*, 2008). Therefore, partial or temporal impediments can impact populations by increasing mortality and predation and decreasing egg production (O'Hanley and Tomberlin, 2005).

The above refers to salmonid production in particular as these electrofishing surveys are designed for juvenile salmonid capture. This questions, to an even greater extent than for salmonids, the validity of assessing barriers for other species using such data. For example, juvenile lampreys are to be found buried within the substrate and lamprey-specific electrofishing surveys concentrate on a small area of suitable habitat which is fished for prolonged periods of time. The time spent fishing these areas during salmonid surveys will be less than required to capture all juvenile lampreys present and so is unlikely to give a good population estimate. It may also be the case that the habitat chosen for salmonid surveys is unsuitable for other species. For example, a length of riffle may be chosen for a survey which does not contain any juvenile lamprey habitat, i.e. silt or sand substrate and low water velocities. Finding no lampreys at this site does not necessarily mean that there are none in the vicinity as there may be suitable habitat close to hand. Therefore, attempting to assess the passability of barriers for such guilds of fish using this method is likely to be even less reliable than for salmonids.

There will be obvious exceptions to this where good numbers of known fish species have been found throughout a watercourse and the impact of any structures is deemed to be none or negligible. Alternatively, there may be data that show there are good populations below a structure and none above and the likelihood is that there is a complete barrier to migration. This is a judgement for individual organisations to make within their catchments.

There may also be certain situations where the subjective assessment of a barrier is correct but the cause of the barrier being inaccessible is not. For example, at barrier DE1 it was the opinion of 3 members of Annan DSFB staff that water velocity through the pipes was likely to be a major limiting factor to all cohorts. Visually this appeared to be the case but flow meter measurements showed that for some fish, e.g. adult salmonids, velocity was not likely to be an issue. If it is the intention to have a barrier removed or altered then it would surely be beneficial to have as much information regarding the limiting factors of a structure before progressing to the next stage i.e. specialist assessment.

4.3 Observed Limitations of Survey Methodology

The most obvious limitation of the methodology is that measurements cannot always be recorded, e.g. at high water for health and safety reasons. This makes subjective assessments inevitable and it should be admitted that it is unlikely all results recorded here are 100% accurate. For example, it was not possible to take velocity and depth readings at the fish pass on structure AN1 so subjective assessment was required at all water levels. Opinion was divided between members of Annan DSFB staff as to whether or not the structure was a complete barrier to adult lamprey upstream migration. Electrofishing surveys have captured transformers which have been positively identified as river lampreys (*Lampetra fluviatilis*). However, there is a growing opinion that river lampreys and brook lampreys (*Lampetra planeri*) are one and the same species. The literature suggests that there is gene flow between both and that they may not be as reproductively isolated as previously supposed (e.g. Lasne *et al*, 2010). However, it does not appear to have been documented that non-migratory brook lamprey populations are capable of generating sea-going river lamprey phenotypes in the same way that brown trout populations produce sea trout smolts. Therefore this cannot be cited as a reason for the presence of river lamprey transformers if the barrier is impassable. Also, the fact that no adult river lampreys are known to have been found above this obstruction does not prove they are not there. The speciation status of the above lampreys remains a topic of great interest but for the purposes of this report the main concern is that it is inconclusive as to the barriers passability for adult lampreys.

There also appear to be a few minor issues regarding being unable to record passability scores with the accuracy given against the tables and guidance provided. For example, due to the wave created against a measuring stick, depths could not be recorded to the precision of the figures given for juvenile lamprey migration. It was therefore only possible in some cases to conclude that structures were a complete barrier or a barrier of some description. Also, it is stated in the assessment manual that two water velocities should be recorded at depths of greater than 5cm. This was not practical as the turbine on the velocity meter used was also 5cm. The minimum depth for a second velocity reading was increased to 10cm for this reason. It should be noted that the assessments were conducted using the 2010 manual. There are apparently revisions to the protocol in the 2011 manual which may address some of these minor issues.

4.4 Conclusion

As previously stated, some may be of the opinion that existing population data can give enough information on the passability of barriers. The Annan DSFB has certainly looked at data in some areas and concluded that a structure is of little concern or alternatively that it is impassable to all migratory fish. Nevertheless, it is the opinion of this author that the methodology devised has value in helping to decide if, when and why certain structures are having an effect on fish migration. It was certainly the case that new information was gleaned for at least some of the barriers surveyed in this project. The results produced from such assessments may also add to any existing population data when trying to provide tangible evidence to support the removal or alteration of any obstructions. At the very least, those who attend the barrier to porosity course and carry out some assessments using the protocol are likely to find their knowledge of the topic is increased to some degree.

References

Haro, A., Odeh, M., Noreika, J., and Castro-Santos, T. (1998). *Effect of water acceleration on downstream migratory behaviour and passage of Atlantic salmon smolts and juvenile American shad at surface bypasses*. Transactions of the American Fisheries Society. (127): 118-127.

Kemp, P. S., Russon, I. J., Waterson, B., O'Hanley, J. & Pess, G. P. (2008). *Recommendations for a Coarse Resolution Rapid Assessment Methodology to Assess Barriers to Fish Migration, and Associated Prioritisation Tools*. International Centre for Ecohydraulic Research Report.

Lasne, E., Sabatié, M.R., Evanno, G., (2010). *Communal spawning of brook and river lampreys (Lampetra planeri and L. fluviatilis) is common in the Oir River (France)*. Ecology of Freshwater Fish (19): 323–325.

O'Hanley, J. R., and Tomberlin, D. (2005). *Optimising the removal of small fish passage barriers*. Environmental Modelling and Assessment (10): 85-98.

Scotland & Northern Ireland Forum for Environmental Research (2010). *WFD 111 (2a) Coarse Resolution Rapid-assessment Methodology to Assess Barriers to Fish Migration*. Level A Assessment Field Manual.

Scotland & Northern Ireland Forum for Environmental Research (2011). *Screening Tool for Assessing the Passability of Barriers to Fish Movement*, Training Course – initial information

Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, K. R., and Cushing, C. E. (1980). *The River Continuum Concept*. Canadian Journal of Fisheries and Aquatic Sciences. (37): 130-137.

<u>Websites</u>

Bull, C. (2010) Barriers to Fish Movement: Assessing the impact of individual barriers on the free passage of fish.
http://www.ifm.org.uk/branches/welsh/Session_1_fish_and_barriers.pdf

SNIFFER: Development of a Screening tool for Assessing the Porosity of Barriers to Fish Migration.
http://www.sniffer.org.uk/Resources/WFD111/Layout_SustainableLand/9.aspx?backurl=http%3A%2F%2Fwww.sniffer.org.uk%3A80%2Four-work%2Fsustainable-land-use-and-water-management.aspx&selectedtab=active

Appendix 1

Barrier Assessment Tables

Abbreviations	
Adult salmon:	(AS)
Adult trout:	(AT)
Adult grayling:	(AG)
Cyprinid/juvenile salmonid:	(C/JS)
Adult lamprey:	(AL)
Juvenile eel:	(JE)
Salmonid smolt:	(SS)
Juvenile lamprey:	(JL)
Adult eel:	(AE)
No barrier:	(1.0)
Partial barrier low impact:	(0.6)
Partial barrier high impact:	(0.3)
Complete barrier:	(0.0)
All measurements undertaken:	(AMU)
Measurements partially undertaken:	(MPU)
All measurements estimated:	(AME)

An1 (main-stem Annan: E319009N568229): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	1.0	MPU	1.0	MPU
AS – elevated	1.0	AME	1.0	AME
AS – bankfull	1.0	AME	1.0	AME
AT – low water	1.0	MPU	1.0	MPU
AT – elevated	1.0	AME	1.0	AME
AT – bankfull	1.0	AME	1.0	AME
AG – low water	1.0	MPU	1.0	MPU
AG – elevated	1.0	AME	1.0	AME
AG – bankfull	1.0	AME	1.0	AME
C/JS – low water	0.3	MPU	1.0	MPU
C/JS – elevated	0.3	AME	1.0	AME
C/JS – bankfull	0.3	AME	1.0	AME
AL – low water	0.0	MPU		
AL - elevated	0.0	AME		
AL – bankfull	0.0	AME		
JE – low water	1.0	MPU		
JE - elevated	1.0	AME		
JE – bankfull	1.0	AME		
SS – low water			1.0	MPU
SS - elevated			1.0	AME
SS – bankfull			1.0	AME
JL – low water			1.0	MPU
JL - elevated			1.0	AME
JL – bankfull			1.0	AME
AE – low water			1.0	MPU
AE - elevated			1.0	AME
AE – bankfull			1.0	AME

MN1 (Mein Water: E320612N574454): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	0.0	AMU	0.0	AMU
AS – elevated	0.6	AME	0.6	AME
AS – bankfull	N/A	N/A	N/A	N/A
AT – low water	0.0	AMU	0.0	AMU
AT – elevated	0.6	AME	0.6	AME
AT – bankfull	N/A	N/A	N/A	N/A
AG – low water	0.0	AMU	0.0	AMU
AG – elevated	0.0	AME	0.6	AME
AG – bankfull	N/A	N/A	N/A	N/A
C/JS – low water	0.0	AMU	0.0	AMU
C/JS – elevated	0.0	AME	0.6	AME
C/JS – bankfull	N/A	N/A	N/A	N/A
AL – low water	0.0	AMU		
AL - elevated	0.0	AME		
AL – bankfull	N/A	N/A		
JE – low water	0.3	AMU		
JE - elevated	0.3	AME		
JE – bankfull	N/A	N/A		
SS – low water			0.3	AMU
SS - elevated			0.6	AME
SS – bankfull			N/A	N/A
JL – low water			0.6	AMU
JL - elevated			0.6	AME
JL – bankfull			N/A	N/A
AE – low water			0.3	AMU
AE - elevated			0.6	AME
AE – bankfull			N/A	N/A

MK1 (E314489N574492): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	0.0	AMU	0.0	AMU
AS – elevated	0.0	AME	1.0	AME
AS – bankfull	0.3	AME	1.0	AME
AT – low water	0.0	AMU	0.0	AMU
AT – elevated	0.0	AME	1.0	AME
AT – bankfull	0.3	AME	1.0	AME
AG – low water	0.0	AMU	0.0	AMU
AG – elevated	0.0	AME	1.0	AME
AG – bankfull	0.0	AME	1.0	AME
C/JS – low water	0.0	AMU	0.0	AMU
C/JS – elevated	0.0	AME	1.0	AME
C/JS – bankfull	0.0	AME	1.0	AME
AL – low water	0.0	AMU		
AL - elevated	0.0	AME		
AL – bankfull	0.0	AME		
JE – low water	1.0	AMU		
JE - elevated	1.0	AME		
JE – bankfull	1.0	AME		
SS – low water			0.3	AMU
SS - elevated			1.0	AME
SS – bankfull			1.0	AME
JL – low water			1.0	AMU
JL - elevated			1.0	AME
JL – bankfull			1.0	AME
AE – low water			1.0	AMU
AE - elevated			1.0	AME
AE – bankfull			1.0	AME

MK2 (E314283N575521): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	0.6	AMU	1.0	AMU
AS – elevated	0.6	AME	1.0	AME
AS – bankfull	0.0	AME	1.0	AME
AT – low water	0.6	AMU	1.0	AMU
AT – elevated	0.6	AME	1.0	AME
AT – bankfull	0.6	AME	1.0	AME
AG – low water	0.6	AMU	1.0	AMU
AG – elevated	0.0	AME	1.0	AME
AG – bankfull	0.3	AME	1.0	AME
C/JS – low water	0.0	AMU	1.0	AMU
C/JS – elevated	0.0	AME	1.0	AME
C/JS – bankfull	0.0	AME	1.0	AME
AL – low water	0.3	AMU		
AL - elevated	0.0	AME		
AL – bankfull	0.0	AME		
JE – low water	1.0	AMU		
JE - elevated	1.0	AME		
JE – bankfull	1.0	AME		
SS – low water			1.0	AMU
SS - elevated			1.0	AME
SS – bankfull			1.0	AME
JL – low water			1.0	AMU
JL - elevated			1.0	AME
JL – bankfull			1.0	AME
AE – low water			1.0	AMU
AE - elevated			1.0	AME
AE – bankfull			1.0	AME

Mk 3 (Water of Milk: E315425N578749): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	0.6	AMU	1.0	AMU
AS – elevated	0.0	AME	1.0	AME
AS – bankfull	0.0	AME	1.0	AME
AT – low water	0.6	AMU	1.0	AMU
AT – elevated	0.0	AME	1.0	AME
AT – bankfull	0.0	AME	1.0	AME
AG – low water	0.6	AMU	1.0	AMU
AG – elevated	0.0	AME	1.0	AME
AG – bankfull	0.0	AME	1.0	AME
C/JS – low water	0.3	AMU	1.0	AMU
C/JS – elevated	0.0	AME	1.0	AME
C/JS – bankfull	0.0	AME	1.0	AME
AL – low water	0.0	AMU		
AL - elevated	0.0	AME		
AL – bankfull	0.0	AME		
JE – low water	0.3	AMU		
JE - elevated	0.3	AME		
JE – bankfull	0.3	AME		
SS – low water			1.0	AMU
SS - elevated			1.0	AME
SS – bankfull			1.0	AME
JL – low water			1.0	AMU
JL - elevated			1.0	AME
JL – bankfull			1.0	AME
AE – low water			1.0	AMU
AE - elevated			1.0	AME
AE – bankfull			1.0	AME

DEHT1 (E314560N588879): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	N/A	N/A	N/A	N/A
AS – elevated	0.0	AMU	0.0	AME
AS – bankfull	0.0	AME	0.0	AME
AT – low water	N/A	N/A	N/A	N/A
AT – elevated	0.0	AMU	0.0	AME
AT – bankfull	0.0	AME	0.0	AME
AG – low water	N/A	N/A	N/A	N/A
AG – elevated	0.0	AMU	0.3	AME
AG – bankfull	0.0	AME	0.3	AME
C/JS – low water	N/A	N/A	N/A	N/A
C/JS – elevated	0.0	AMU	0.3	AME
C/JS – bankfull	0.0	AME	0.3	AME
AL – low water	N/A	N/A		
AL - elevated	0.0	AMU		
AL – bankfull	0.0	AME		
JE – low water	N/A	N/A		
JE - elevated	0.0	AMU		
JE – bankfull	0.0	AME		
SS – low water			N/A	N/A
SS - elevated			0.3	AME
SS – bankfull			0.3	AME
JL – low water			N/A	N/A
JL - elevated			1.0	AME
JL – bankfull			1.0	AME
AE – low water			N/A	N/A
AE - elevated			0.3	AME
AE – bankfull			0.3	AME

DEHT2 (E314523N588908): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	N/A	N/A	N/A	N/A
AS – elevated	0.0	AMU	0.0	AME
AS – bankfull	0.0	AME	0.0	AME
AT – low water	N/A	N/A	N/A	N/A
AT – elevated	0.0	AMU	0.0	AME
AT – bankfull	0.0	AME	0.0	AME
AG – low water	N/A	N/A	N/A	N/A
AG – elevated	0.0	AMU	0.0	AME
AG – bankfull	0.0	AME	0.0	AME
C/JS – low water	N/A	N/A	N/A	N/A
C/JS – elevated	0.0	AMU	0.0	AME
C/JS – bankfull	0.0	AME	0.0	AME
AL – low water	N/A	N/A		
AL - elevated	0.0	AMU		
AL – bankfull	0.0	AME		
JE – low water	N/A	N/A		
JE - elevated	0.0	AMU		
JE – bankfull	0.0	AME		
SS – low water			N/A	N/A
SS - elevated			0.0	AME
SS – bankfull			0.0	AME
JL – low water			N/A	N/A
JL - elevated			0.3	AME
JL – bankfull			0.3	AME
AE – low water			N/A	N/A
AE - elevated			0.0	AME
AE – bankfull			0.0	AME

DE1 (E317046N599907): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	N/A	N/A	N/A	N/A
AS – elevated	0.3	AMU	0.6	AME
AS – bankfull	0.3	AME	0.6	AME
AT – low water	N/A	N/A	N/A	N/A
AT – elevated	0.3	AMU	0.6	AME
AT – bankfull	0.3	AME	0.6	AME
AG – low water	N/A	N/A	N/A	N/A
AG – elevated	0.3	AMU	0.6	AME
AG – bankfull	0.3	AME	0.6	AME
C/JS – low water	N/A	N/A	N/A	N/A
C/JS – elevated	0.3	AMU	0.6	AME
C/JS – bankfull	0.3	AME	0.6	AME
AL – low water	N/A	N/A		
AL - elevated	0.3	AMU		
AL – bankfull	0.3	AME		
JE – low water	N/A	N/A		
JE - elevated	0.6	AMU		
JE – bankfull	0.6	AME		
SS – low water			N/A	N/A
SS - elevated			0.6	AME
SS – bankfull			0.6	AME
JL – low water			N/A	N/A
JL - elevated			0.6	AME
JL – bankfull			0.6	AME
AE – low water			N/A	N/A
AE - elevated			0.6	AME
AE – bankfull			0.6	AME

WY1 (Wamphray Water: E311250N595730): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	0.0	AMU	0.6	AMU
AS – elevated	0.0	AME	0.6	AME
AS – bankfull	0.0	AME	0.6	AME
AT – low water	0.0	AMU	0.6	AMU
AT – elevated	0.0	AME	0.6	AME
AT – bankfull	0.0	AME	0.6	AME
AG – low water	0.0	AMU	1.0	AMU
AG – elevated	0.0	AME	1.0	AME
AG – bankfull	0.0	AME	1.0	AME
C/JS – low water	0.0	AMU	1.0	AMU
C/JS – elevated	0.0	AME	1.0	AME
C/JS – bankfull	0.0	AME	1.0	AME
AL – low water	0.0	AMU		
AL - elevated	0.0	AME		
AL – bankfull	0.0	AME		
JE – low water	0.0	AMU		
JE - elevated	0.0	AME		
JE – bankfull	0.0	AME		
SS – low water			1.0	AMU
SS - elevated			1.0	AME
SS – bankfull			1.0	AME
JL – low water			1.0	AMU
JL - elevated			1.0	AME
JL – bankfull			1.0	AME
AE – low water			1.0	AMU
AE - elevated			1.0	AME
AE – bankfull			1.0	AME

ENCN1 (Evan Water, Cloffin Burn: E304856N606635): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	0.0	AMU	0.3	AMU
AS – elevated	N/A	N/A	N/A	N/A
AS – bankfull	0.3	AME	0.6	AME
AT – low water	0.0	AMU	0.3	AMU
AT – elevated	N/A	N/A	N/A	N/A
AT – bankfull	0.3	AME	0.6	AME
AG – low water	0.0	AMU	0.3	AMU
AG – elevated	N/A	N/A	N/A	N/A
AG – bankfull	0.0	AME	0.6	AME
C/JS – low water	0.0	AMU	0.6	AMU
C/JS – elevated	N/A	N/A	N/A	N/A
C/JS – bankfull	0.0	AME	1.0	AME
AL – low water	0.0	AMU		
AL - elevated	N/A	N/A		
AL – bankfull	0.0	AME		
JE – low water	0.0	AMU		
JE - elevated	N/A	N/A		
JE – bankfull	0.0	AME		
SS – low water			0.6	AMU
SS - elevated			N/A	N/A
SS – bankfull			1.0	AME
JL – low water			1.0	AMU
JL - elevated			N/A	N/A
JL – bankfull			1.0	AME
AE – low water			0.6	AMU
AE - elevated			N/A	N/A

EN1 (Evan Water: E299973N614373): Final Passability Assessment

Fish Type & Conditions	U/S Impact	U/S Estimation	D/S Impact	D/S Estimation
AS – low water	0.0	AMU	0.3	AMU
AS – elevated	0.0	AME	0.3	AME
AS – bankfull	0.0	AME	0.3	AME
AT – low water	0.0	AMU	0.3	AMU
AT – elevated	0.0	AME	0.3	AME
AT – bankfull	0.0	AME	0.3	AME
AG – low water	0.0	AMU	0.3	AMU
AG – elevated	0.0	AME	0.3	AME
AG – bankfull	0.0	AME	0.3	AME
C/JS – low water	0.0	AMU	0.3	AMU
C/JS – elevated	0.0	AME	0.3	AME
C/JS – bankfull	0.0	AME	0.3	AME
AL – low water	0.0	AMU		
AL - elevated	0.0	AME		
AL – bankfull	0.0	AME		
JE – low water	0.0	AMU		
JE - elevated	0.0	AME		
JE – bankfull	0.0	AME		
SS – low water			0.6	AMU
SS - elevated			0.6	AME
SS – bankfull			0.6	AME
JL – low water			1.0	AMU
JL - elevated			1.0	AME
JL – bankfull			1.0	AME
AE – low water			0.6	AMU
AE - elevated			0.6	AME
AE – bankfull			0.6	AME